Attorney's Docket No.: 09752-091001

APPLICATION

FOR

UNITED STATES LETTERS PATENT

TITLE: COMMUNICATION OF LOCATION INFORMATION IN A WIRELESS COMMUNICATION SYSTEM

APPLICANT: JASON F. HUNZINGER

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COMMUNICATION OF LOCATION INFORMATION IN A WIRELESS COMMUNICATION SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims benefit of U.S. Provisional application No. 60/213,213, filed June 21, 2000.

TECHNICAL FIELD

This invention relates to wireless communication systems, and more particularly to enhanced handoff control within wireless communication systems.

BACKGROUND

The present invention communicates position location and movement tracking information between a mobile station, such as a cellular or Personal Communication Services (PCS) phone, and a wireless communication infrastructure. In particular, implementation of the present invention as an extension and modification of methods, data structures, and hardware structures for message transfer, as described by the Wireless Application Protocol Wireless Telephony Application Interface Specification, WAP WTAI (GSM), WAP-171-WTAIGSM, Version 07-Jul-2000, published by the Wireless Application Protocol Forum, Ltd., herein incorporated by reference, and used with a code division multiple access (CDMA) wireless communication system, is a preferred embodiment. Said CDMA

wireless communication system is fully described by the following standards, all or which are published by the TELECOMMUNICATIONS INDUSTRY ASSOCIATION, Standards & Technology Department, 2500 Wilson Blvd., Arlington, VA 22201, and all of which are herein incorporated by reference: TIA/EIA-95B, published February 1, 1999; TIA/EIA/IS-2000,1-A, published March 1, 2000; TIA/EIA/IS-707, published February 1998;TIA/EIA/IS-707-A, Published March, 1999, TIA/EIA/IS-707-A-1, published December, 1999; and, TIA/EIA/IS-707-A-2, published June, 2000. The further implementation of this invention with other messaging protocols and data structures and wireless communication systems is straightforward to one skilled in the art.

SUMMARY

A system for communicating information related to the position of a mobile station within a wireless communication infrastructure, comprising: a mobile station capable of transmitting and receiving signals to and from a wireless communication infrastructure using code division multiple access techniques; a wireless communication infrastructure that can transmit and receive signals to and from a mobile station using code division multiple access techniques; and a data server capable of communicating with

said wireless communication infrastructure; wherein said mobile station and said data server communicate via said wireless communication infrastructure using formatted messages representing wireless communication infrastructure state information related to said mobile station's position within the service area of said wireless communication infrastructure.

DESCRIPTION OF DRAWINGS

These and other features and advantages of the invention will become more apparent upon reading the following detailed description and upon reference to the accompanying drawings.

Figure 1 is a diagram of a roving mobile communication terminal moving amongst different locations between sectors in a wireless communication system.

Figure 2 depicts a wireless communication infrastructure interposed between a roving mobile terminal and a data server.

Figure 3 is a protocol layer diagram of a mobile station, an optional Wireless Application Protocol (WAP) gateway, and a data server.

Figure 4 is a system architecture diagram of functions and components of the mobile station and server that relate to the new invention.

DETAILED DESCRIPTION

The present invention comprises methods, data structures, and apparatus for enabling communication, via a wireless infrastructure, of information that is incidental to the operation of a mobile station (MS) within the wireless infrastructure, said information being useful for estimating the location of said mobile station for local, remote, or distributed services based upon the mobile station location that may reside locally at the mobile station, remotely, at a remote data server, or jointly between a mobile station and a remote data server. Examples of such services based upon a mobile station location include local weather reports, finding the nearest service station, restaurant, etc. Similarly, such mobile station location information can be stored, over time, either locally at the mobile station, remotely at the data server, or jointly between a mobile station and a remote data server, and used to extrapolate the movement, or trajectory, of a roving mobile station.

Figure 1 depicts an example of a mobile station 101 that roves through a geographic area served by a wireless infrastructure including a first base station (BS) 121 with wireless sectors A 110 and sector B 111, and a second BS 122, with a sector C 112. In the course of such roving, mobile station 101 travels from position A 131 to position B 132 to

position C 133, and as a matter of course, experiences a number of wireless communication infrastructure context states, and state transitions, hereafter referred to as "network contexts". One way of specifying network context is a set of System Identification (SID), Network Identification (NID), Base Station Identification (BS_ID), and Sector Pseudo-Noise offset (PN). Consider that the base stations and sectors in Figure 1 have the same SID and NID. The BS_ID and PN that the mobile station 101 is monitoring identify the different positions of the mobile station 101. For example, a mobile station that is monitoring the first base station 121 and sector A 110 is likely to be in the area defined by the dotted line of Sector A 110, such as the position "A" 131. Such network parameters can be used to differentiate mobile station different positions such as from Position "B" 132 and Position "C" 133. By retaining past positions of a roving mobile station, it is possible to determine the position track that the rover has followed over time, and to extrapolate a future position. The extrapolation of the future position may be done on the basis of a simple, linear, trajectory calculation, or the extrapolation may be further modified by prior knowledge, stored in a data server, of geographic or topographical constraints on the rover's trajectory.

Figure 2 depicts a generic structure of a wireless infrastructure 320. A client mobile station's (MS's) 101 general location may be estimated by reporting the base station sector, base station 231, or other network context information, through a base station controller (BSC) 233 that may control a cell cluster 232, through a mobile switching center (MSC) 234, through a Packet Data Switching Network (PDSN) or Inter-working Function (IWF) 235, and through an optional WAP gateway 236, to a data server 237. The data server 237 is capable of converting the base station sector, base station, or other network context information to a geographic location estimate of mobile station 101. Such a location estimate may be in terms of latitude or longitude, or in terms of geographic sectors defined on the basis of other factors such as known shopping center areas, industrial campus areas, transportation terminal facilities, or similar areas of grouped activities or interests. Such an estimated location of the mobile station 101 can also be correlated with information stored in a database addressable by a server 237 that contains information relevant to the mobile station 101 at that mobile station's particular estimated location.

Furthermore, if multiple, sequential location estimates of the mobile station 101 have been determined, an estimate of the trajectory of motion for the mobile station can also be

determined, using well-known extrapolation techniques, possible constrained with known geographic or topographical constraint information. This will further allow correlation of the mobile station's estimated position and estimated trajectory with information stored in a database addressable by the server 237 that responds with information relevant to a mobile station at that particular mobile station's estimated location, and on that particular mobile station's estimated trajectory.

Alternately, a mobile station 101 may monitor the network context or be updated by the bearer service of events that change the current network parameters such as communicated by cell-to-cell, cell sector-to-cell sector, or wireless system-to-wireless system handoff message from the infrastructure. Such information can be stored within the mobile station 101. Additionally, the mobile station 101 may store a sequential record of such information providing the basis for position estimation and trajectory estimation, as previously discussed. Such information may then be later conveyed to a server 237, as described above, if and when requested by the server 237, or if and when desired by the mobile station 101 or mobile station operator.

Figure 4 shows an aspect of location-related components embodied within the mobile station side 301 and server side 302. The mobile station 101 may estimate location or trajectory

based on such network information or subsets of this network information to applications 310 or services 312 that reside within the mobile station 101, or to application 322 or service 232 residing on a remote server 237. The location or trajectory information can be provided to the remote server side 302 via mobile originated Short-Message-Service (SMS) or browser calls (packet or circuit switched data). The mobile station 101 may communicate such information to a local application or service such as Wireless Markup Language Script (WMLScript) via a Wireless Application Protocol (WAP) Wireless Telephony Application Interface (WTAI) extension or to a local or custom handset application via internal function calls or messaging such as through an Application Programming Interface 314. A mobile station may provide such location information to a remote service that is enabling a remote application directly by a service-to-service interface 304 or applications may communicate such information amongst themselves by a direct application-to-application interface 303.

This invention teaches methods, apparatus, and data structures for mobile stations to provide such location-based services with location context information in a standardized format.

The information can be exchanged in the form of a string (ASCII text string) or equivalent binary format. The string or

set of octal fields consists of one or more location records each consisting of several fields.

Table 1 shows a standard string or octal/binary format for the network information. This format is such that the most critical information is provided first/earliest in case that some information relating to past mobile station positions needs to be truncated owing to data storage limitations.

Table 1: Header Format

NO_REC	Number of Location Records	(1 or more depending on maximum string size)

Followed by NO_REC occurrences of the following:

	Marker	'@'
LOC_TYPE	Location Information Type	See Table 1.
LOC_TIME_STAMP	Time Stamp	Time stamp if available or omitted.
LOC_REC	Location Information Record	See record description according to LOC_TYPE.

The time stamp (LOC_TIME_STAMP) may be:

1) Omitted if unavailable or deemed unnecessary.

2) Absolute in the format "hh:mm:ss.ms" or other standard format

3) Relative in the format "hh:mm:ss.ms" or other standard format

The standard format for CDMA records is specified below in Table 2. All fields shall be separated by a comma, i.e. "," unless otherwise stated.

Table 2: CDMA Record Format

MCC	Mobile Country Code	Value or blank if unknown
UZID	User Zone ID	Value or blank if unknown
REG_ZONE	Registration Zone ID	Value or blank if unknown
SID	System ID	Value
NID	Network ID	Value
CDMA_CH	CDMA Channel	Value
OFFSET_RES	PN Offset Resolution	See Table 2.
RSSI	Received Signal Strength	Value (-ve dBs rounded to integer)
TX_PWR	Transmit Power.	Value
D_INCL	Dynamics Info Included	Y (if included), blank if not

Followed by the fields below if D_INCL is set to "Y". Each field is followed by ",".

P_SID	Previous SID	Value
P_NID	Previous NID	Value
P_CDMA_CH	Previous CDMA	Value

	Channel	
TIME_CONSTANT	Time constant for dynamics	Value followed directly by units (See Table 3)

Followed by the mandatory field(s) below.

	Marker Text	"BS"
NO_BS	Number of Base Station records	Integer (0 to MAX_NO_BS)
	Marker Text	":"

Followed by NO_BS occurrences of the fields below. The BS_REC and BS_D_REC blocks shall be ordered in decreasing order of sector signal quality. Given limited space, sectors with the worst signal strength shall be omitted.

BS_REC(i)	Base Station/Sector i's basic record	See BS_REC description
BS_D_REC(i)	Base Station/Sector i's dynamics record	Omitted unless D_INCL is set to "Y" - See below.
	Marker	";"

The format of each BS_REC(i) block is as follows. Each field, except the last in the block, shall be followed by a ",".

BS_ID(i)	Base Station i's ID	Value or blank if unknown
BS_LAT(i)	Base Station i's Latitude	Value or blank if unknown
BS_LON(i)	Base Station i's Longitude	Value or blank if unknown
PILOT_PN(i)	Sector i's Pilot PN value	Value
ECIO(I)	Sector i's measured pilot Ec/Io	-1/2dB value (rounded to integer)
PN_OFFSET(i)	Sector i's PN offset relative to reference Sector's PN offset	Value in units of OFFSET_RES (blank if reference or zero)
STATUS(i)	Sector's status	See Table 4.

The format of each BS_D_REC(i) block is as follows. Each field, except the last in the block, shall be followed by a ",".

	Marker	":"
P_STATUS(i)	Sector i's previous status	See Table 4.
D_ECIO(i)	Sector i's Ec/Io derivative	Value in units of -1/2dBs (rounded to integer)
D_OFFSET(i)	Sector i's offset derivative.	Value in units of OFFSET_RES (blank if zero)

Table 3 shows the valid values for PN offset resolutions.

Table 4 shows valid values for time constant (TIME_CONSTANT)

units indicator. Table 4 shows valid values for sector pilots in terms of link maintenance.

Table 3: OFFSET_RES Values

Offset Resolution	**Field Text**
1 chip	1
½ chip	2
¼ chip	4
1/8 chip	8
1/16 chip	16
Etc.	Etc.

Table 4: TIME_CONSTANT Units Indicator

Time Constant Units	**Field Text**
Milliseconds	"ms"
Seconds	"s"
Minutes	"m"
Hours	"h"
Reserved	Reserved

Table 5: STATUS and P_STATUS Values

Status	**Field Text**
Active Set Pilot	A
Desired (Candidate or Neighbor being considered for handoff)	D
Neighbor	N
Remaining Set Pilot	R
Candidate Frequency Pilot	C

Table 6 lists the value LOC_TYPE values for location record type. The standard is designed to be compatible with existing GSM WAP based standards for location information.

Table 6: LOC_TYPE Values

Location Type	**Field Text**
CDMA (IS-95A/B, IS-2000, J-STD-008,etc)	"C"
WGS-84 (GPS coordinates)	"1"
GPS	TBD
GSM	"3" (see APPENDIX)
Reserved	Reserved

An alternative to using a custom format for some of the location related network information is to use IS-2000 pilot strength measurement message formats (For example: Pilot Strength Measurement Message (PSMM) or Mini-Message (PSMMM)).

The mobile station 101 provides access to the location related information through a WAP Wireless Telephony Application interface (WTAI) or through a function accessible by browser scripts (WMLScript for example) or other programs. The interface application programming interface (API) 314 can also support specifying the maximum size or length of information that may be returned. For example, if the information is returned as an ASCII string for providing the result as a Uniform Resource Locator (URL) post, then only a

limited string length can be used. The mobile station 101 may use this restriction to select the most applicable information that can fit in the desired size. Additionally, the API 314 may allow the caller to select alert-type feedback when a location or network condition occurs such as a handoff between sector B 111 and sector C 112 exhibited in Figure 1. A callback function or script can be provided such that the function or script is invoked once the condition arises.

Figure 3 shows the typical protocol architecture of the client mobile station 101, the WAP gateway 236, and the end server 237. The protocol layers include Wireless Application Environment (WAE), Hypertext transfer protocol (HTTP), Transport Layer Security (TLS), Wireless TCP (W-TCP), IP, Point-to-Point Protocol (PPP), Radio-Link Protocol (RLP), and Layer 1 (Physical Layer). PPP, RLP and L1 are used between mobile station and wireless infrastructure 320. The optional gateway converts the upper layer protocols from the wireless domain to the internet domain if necessary.

Figure 4 further shows a mobile station 101 implementation consisting of: (a) an API 314 in the form of a set of functions, procedures or parameters; (b) a response generating component 316 that compiles the required information; and, (c) a condition detection component 318 that monitors location-related network conditions (including links

to the call-processing or bearer service stack software to poll or request updates).

A generating component 316 within the mobile station takes network information and (i) selects the most appropriate information, i.e. that information that is most differentiating of the current location or conditions,(ii) eliminates redundant information, (iii) prioritizes the information elements and, (iv) compiles the network information response of the requested size containing the highest priority items.

The generating component 316 may keep its own database of the most recent network information. The monitoring component 318 may request from the call processing stack (layers 1 through 4) any updates of the information. The monitoring component 318 may receive updates from the stack on various network information items according to its requests. For example, it may receive updates on a specific time basis or degree of change depending on: (a) whether or not a location process is underway, and (b) the precision or accuracy requirements of the location-based activities.

For example, the call-processing entity may update the generating entity when a handoff occurs and a call or connection can be brought up only when necessary to inform the server of a location. Similarly, the generating entity may

communicate the information, requested by a local application, and the local application may determine if it is necessary to update a server. In general, the bearer service component, collects dynamics information, CDMA physical layer details, link maintenance information as well as system level information from the CDMA stack.

The CDMA network information may be generated and cached for applications or scripts. The information may be cached in a variety of formats. The information may be cached in the mobile bearer service, WAP layers, scripts, or other local applications or services or on a server or network entity.

There may be varying levels of privacy and associated location items or precision to be reported. This can be accomplished by providing the user with options to select the desired degree of privacy in terms of which network items or set of network information to disclose. In addition an identified or key may be used to signify that the carrier or user have agreed to disclose the information to a script or remote server. This key is input to the generating entity.

If privacy is activated, the software must check that the user or carrier have enabled the release of network information to local or remote applications. There may be varying levels of privacy and associated location items or precision to be reported. This can be accomplished by

providing the user with options to select the desired degree of privacy in terms of which network items or set of network information to disclose. In addition an identification or key may be used to signify that the carrier or user have agreed to disclose the information to a script or remote server. This key is input to the generating entity.

These combinations of privacy may be individually selected by the user or carrier to be turned on or off. An application may specify if it is local or remote or give an ID to the software in order to support verification of these items before releasing the location-sensitive information. The mobile station may release a varying degree of information depending on privacy level or accuracy level requested or permitted. For example, the mobile may release chip offsets at lower resolution if privacy is restricted to a certain point.

A sophisticated server can strategically formulate scripts, programs or requests to such a mobile station to enable a mobile station to perform location-based services. The server that receives the location information from the mobile can adaptively correlate non-GPS information such as dynamics information, CDMA physical layer details, link maintenance information and system level information to specific locations determined by GPS receivers and thus use non-GPS information to determine user locations. This is

accomplished by correlating the non-GPS information that is received with the information stored in a database. The database contains the learned (adapted) information.

Consider the following example of an application: a server sends the mobile station a program or script that continuously checks if the mobile is at the desired location by monitoring the network information through the mobile station bearer service software. Once the mobile arrives at the desired location an alert is sent back to the server for tracking purposes. The invention provides a way to overcome inefficient polling by requesting a callback or update internally to the mobile station. The server can also translate a position represented as a (latitude, longitude) coordinate pair to a set of network information describing the same position. The mobile station can compare the provided network information with current network conditions. This allows the mobile to perform the location check without assistance from the server or network. The mobile station can alert a local or remote application once it has arrived and the position(s) described by the network information. The mobile can do this without any GPS technology or network assistance.

In IS-95 and cdma2000 based systems, the mobile station may only determine base station IDs from overheads. The

overheads from a base station may only include that base station's ID. Therefore, mobile stations are not able to provide a server with base station IDs other than the serving cell. This problem can be overcome by storing BS IDs in the mobile station memory. The mobile can maintain a database of recent BS IDs cross references with PNs and SID/NIDs. Then, when making a location information update, the mobile can look up BS IDs in the database using PN, SID, NID for example, as the key.

The mobile station 101 can provide dynamics information in addition to static network information. The dynamics information includes previous SID, NID, channel, etc so that the application or server can determine which direction the mobile station has been traveling in or where within the new cell the mobile is likely to be. There may be a greater likelihood that the mobile is between the current and previous cells than elsewhere in the new cell. Additionally, a TIME_CONSTANT field allows the mobile to inform the server of the time delay associated with the dynamics information. The server may thereby compute the average speed of travel of the mobile and perform predictions on future movement and future locations.

Since the mobile may supply derivatives of Ec/Io and Phase offsets, the server can compute the speed component of

the mobile in the direction toward or away from each base station. Knowing the base station locations the server can compute the mobile's location more accurately. For example, the server can use an iterative Kalman filter to converge on the phase integer ambiguities rather than performing a search for those ambiguities based on a single snapshot of the phase measurements. General filtering and search methods are well known in the GPS field.

Although the present invention has been fully described in connection with the preferred embodiments thereof with reference to the accompanying drawings, it is to be noted that various changes and modifications will become apparent to those skilled in the art. Such changes and modifications are to be understood as being included within the scope of the present invention as defined by the appended claims.